Proceedings of the 6th European VLBI Network Symposium
Ros, E., Porcas, R.W., Lobanov, A.P., & Zensus, J.A. (eds.)
June 25th-28th 2002, Bonn, Germany

1st Global mm-VLBI at 512 Mbit/s

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Abstract. At the end of the 86 GHz CMVA session in October 2001, a first mm-VLBI observation was conducted which used a recording bit-rate of 512 Mbits/s utilizing the Mk IV recording system. The four radio telescopes involved were Onsala, Effelsberg, Pico Veleta, and Haystack. In 20 hours of observing time 8 sources — 1156+295, 1633+382, 1803+784, 3C273, 3C274, 3C345, 3C454.3, BL Lac — were observed in a snapshot-like mode. All sources could be detected thanks to the 40% sensitivity increase obtained by doubling the usual recording rate, and simple maps could be made.

1. Introduction

When the Mk IV VLBI system was proposed several years ago, its main purpose was to provide an increased recording bit-rate for VLBI observations. While the initial aim of 1 Gbit/s seems to be too ambitious and beyond the capabilities of present day Mk IV recorders — at least in a standard "production" environment — recording at 512 Mbit/s can be done in a fairly robust way. The Mk IV upgrade to the old European Mk III VLBI terminals and the newer VLBA recording systems had been finished at about the middle of 2001. So it seemed timely to make use of this potential increase in sensitivity of about 40% for mm-VLBI. A 512 Mbit/s experiment was scheduled in the Coordinated Millimetre VLBI Array session in October of 2001. Its aim was to increase the sensitivity of mm-VLBI and to increase the number of observable sources at these short wavelengths. As the VLBA antennas cannot sustain this high recording bit-rate for more than a few hours, the observing project had to be restricted to Haystack and the European, CMVA antennas.

2. The Observation

20 hours of observing time were scheduled for the 512 Mbit observation at the end of the October 2001 CMVA session. The participating telescopes were the 20 m telescope in Onsala (Sweden), the 100 m telescope in Effelsberg (Germany), the 30 m dish on Pico Veleta (Spain), and the 37 m telescope at Haystack Observatory (see table 1 for details). The 14 m telescope in Metsähovi participated as well, but could only record half the bandwidth, as their Mk IV terminal was not equipped for 512 Mbit/s.

We observed left circular polarization only, to maximize the detection sensitivity. In the recording mode chosen, 8 channels of 16 MHz bandwidth each were used, spanning a total bandwidth of 128 MHz. The data were digitized using 2-bit sampling. This mode is one of two possible modes for recording 512 Mbit/s. It was chosen as it uses the same channel bit-rates as the only possible mode that can be used to record 1 Gbit/s with the Mk V system which will probably be deployed towards the end of 2002. This aspect of the experiment was meant to test the Mk IV correlator's performance for the Mk V system.

We selected bright, well-known VLBI sources with flat mm-spectra.

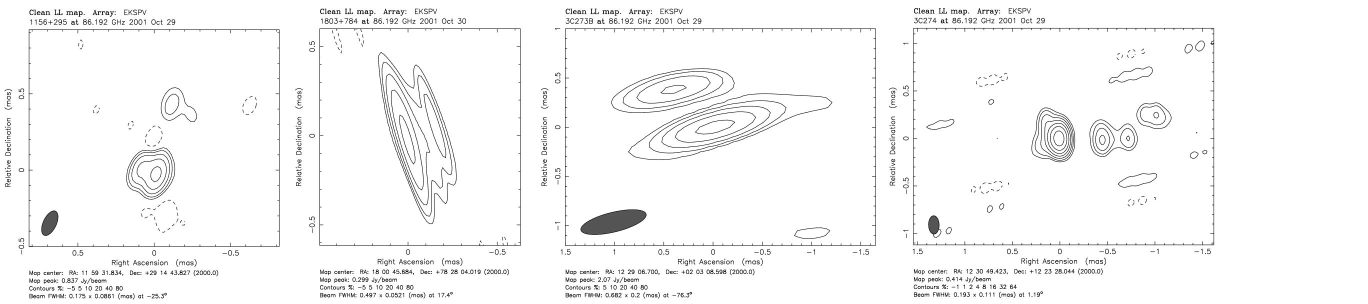
Table 1. Antenna properties:

Telescope	D [m]	$T_{sys} [K]$	DPFU
Onsala 60	20	350	0.055
Effelsberg	100	130	0.133
Pico Veleta	30	120	0.140
Haystack	37	200	0.047

3. Data Reduction

The data were correlated with the MPIfR Mk IV correlator in Bonn. Data bit rates of 512 Mbit/s and more, which have to be recorded with more than 32 tracks per pass must be correlated in two passes, as the playback units are only equipped with one reproduce head (=32 tracks). In each pass, one half of the total recorded bandwidth is correlated. Each of the correlations is treated like an individual experiment at the correlator.

The high channel bit-rates of the recording mode revealed problems with the station units and the software for dealing with the phase-calibration signals. The phase-cal signals are extracted by the station units and are sent to the correlator control computer. A timing problem in the software made the phase-cal signals unusable. To reduce the effects of sporadic station unit failures, the observation was correlated twice and the best data was selected for export to AIPS. The data of each of the two



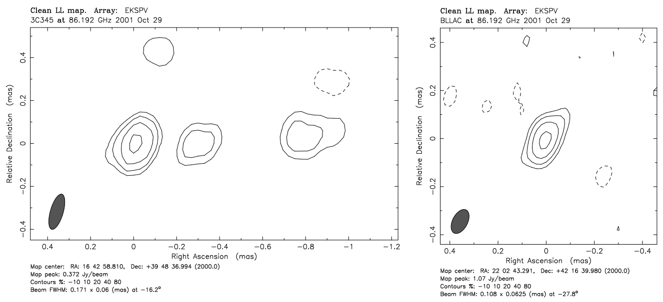


Fig. 1. The maps of 1156+295, 1803+784, 3C273, 3C274 (top), 3C 345, and BL Lac (bottom). The extension of 1156+295 to the north is also seen 15 GHz (1998). The jet component of 1803+784 is on the same side of the core as seen at lower frequencies. The (u, v)-coverage of the data set is only good enough to show 2 components of the jet of 3C273. The map of 3C 274 is the best one of this sample due to a good (u, v)-coverage. The maps of 3C 345 and BL Lac suffer from sparse (u, v)-coverages and the fact that Pico Veleta did not observe these two sources.

sub-experiments of the "sub-bands" was fringe-fitted with `fourfit` from the HOPS package (Haystack Observatory) using manual phase-cals. The main purpose of this fringe-fitting step was to define necessary phase-corrections and to write the raw correlated data in the cross-spectral domain, which was then read into AIPS with `MK4IN`, a new AIPS task written at MPIfR (see Alef & Graham, these proceedings).

The two AIPS data files had to be `UVSRT`ed and could then be combined with the AIPS task `VBGLU` to form the original contiguous 128 MHz bandwidth which had been observed (for an example see Fig. 2 in Alef & Graham, these proceedings). Unfortunately, using manual phase-cals in the `fourfit` step implies that the multi-band delay residuals of the two sub-experiments will not be referred to the same physical location and thus the phase slope across the band will be different for both halves of the band. So the inter-IF phase differences had to be determined again with the help of a short piece of data on a strong source. The way this is done in AIPS requires that the interferometer signal is detected with sufficient SNR in each IF of all antennas roughly within the coherence time of the interferometer. This is difficult at 86 GHz where the coherence time is of the order of 20 s. If too long an integration time is chosen for this manual phase-cal step, the inter IF phases will start to diverge again for earlier and later scans. So it is evident how important measured phase-cal signals will be for future observations at the highest frequencies with the maximal possible bit-rates.

After the reconstruction of the original 128 MHz bandwidth, the data were fringe-fitted with the standard AIPS task `FRING`. The amplitudes were calibrated with the measured system temperatures, gain curves, and antenna efficiencies. Corrections for the opacity of the atmosphere are vital and were determined, too. Unfortunately, the system temperature measurements and the gain curves are not very precise at 86 GHz and as a result the errors of the amplitude calibration are quite large. They can reach a factor of 2 or more. Obvious erroneous system temperature measurements were determined graphically and edited out before they were read into AIPS. The data were `SPLIT`ed and at the same time averaged in frequency.

As the coverage of the UV-plane was sparse for all observed sources only simple maps with one to three components were made with `difmap` (Shepherd et al. 1994). For some stations, calibration scale factors were determined at the same time and were fed back via AIPS.

4. Maps

The theoretically achievable noise in the maps ranges from about 40 to 60 mJy/beam, for the part of the observation where Pico Veleta did not participate, to 3 to 10 mJy/beam, for the other maps. We achieved a noise level in the maps which was typically 3 to 5 times above the thermal noise. Two of the sources — 1633+382 and 3C454.3 — could only be mapped as unresolved point sources. The other maps show some structure which is in all cases consistent with those found by other observers.

5. Summary

We have shown that mm-VLBI observations with a bit-rate of 512 Mbit/s can be done in a standard way. As the bug which prevented us from using the measured phase-cals has been fixed by now, the need for manual phase-cal determination in AIPS is obsolete. If a 16 channel mode for recording 512 Mbit/s is chosen, the station units will cause significantly fewer problems during the correlation.

References

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